LEARNING THE TOOL AND DIE MAKER TRADE

UNITED STATES DEPARTMENT OF LABOR / Manpower Administration

MANPOWER RESEARCH MONOGRAPH No. 17

Manpower Research
Monograph No. 17
1970

LEARNING THE TOOL AND DIE MAKER TRADE

U.S. DEPARTMENT OF LABOR
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Manpower Administration

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 30 cents

PREFACE

This monograph is one in a series being published by the Manpower Administration of the U.S. Department of Labor. It reports on a study of how men become tool and die makers, by Morris A. Horowitz and Irwin L. Herrnstadt at Northeastern University. The full report, "A Study of the Training of Tool and Die Makers," may be purchased from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151, Accession No. PB-187 558. Copies may also be obtained from the Department of Economics, Northeastern University, Boston, Mass. 02115.

This study is part of a twofold research approach sponsored by the Office of Manpower Research of the Manpower Administration's Office of Policy, Evaluation, and Research, to acquire some insights into how craft training is accomplished and how it can be improved. The other part—a study of apprenticeship in four trades by Alfred S. Drew, at the School of Technology of Purdue University—is scheduled for completion in 1970.

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INTRODUCTION

Since the 27.5 million blue-collar workers in our society are so critically important to the economy, it is surprising how little is known about how these workers—who comprise a third of our work force—get their training. Recently, the Department of Labor has been attempting to find out how the 10 million craftsmen among these blue-collar workers acquire their skills.

One of the earliest research projects in this area sponsored by the Office of Manpower Research of the Department's Manpower Administration, under the Department's responsibility to develop information about the supply of American workers,[1] was the first nationwide survey of the vocational training background of workers between the ages of 22 and 64 who had completed less than 3 years of college.[2] This study established base line information about the training of the nonprofessional segment of our labor force. Only about 40 percent of the craftsmen said they had learned their current jobs through formal training, including apprenticeship and vocational courses in school. Only 40 percent of those with formal training thought it was the most helpful way of learning, whereas almost 40 percent of all craftsmen said on-the-job learning was best.

The extent of formal training varied considerably by occupation. About three out of four compositors and typesetters, electricians, and sheet-metal workers had learned their trade formally, but only about one-fourth of the painters and one-third of the carpenters had received formal training. A little more than one-half of the machinists had some formal training, as had almost two-thirds of the toolmakers and diemakers.

If so many of the craftsmen had not learned their trades through formal training, then how did they acquire their skills? According to this study, most of them had "just picked up" the necessary skills on the job through exposure to a variety of work experience.

Some substantiating evidence appears in a study recently conducted for the Department of Labor, in which the author reported that only 12 percent of the young white men 14 to 17 years of age were enrolled in vocational and commercial curriculums, and 15 percent of the Negroes were in these curriculums.[3] Of the 4.5 million white men 14 to 24 years of age with 12 or fewer years of education who were not enrolled in school in 1966, some 2.4 million had no vocational training other than what they may have acquired while attending school.

The study of the training of tool and die makers discussed in this monograph was made because, although a relatively small group, these workers are crucial to the economy and are in short supply. In 1968 there were 200,000 of them employed; allowing for replacements and some growth, their number is expected to reach about 220,000 in 1975.

The researchers, Morris A. Horowitz and Irwin L. Herrnstadt, interviewed 400 tool and die makers and over 60 foremen in more than 50 metalworking and fabricating plants in the Boston area. They also interviewed management personnel, educators, public officials, vocational high school seniors, and new job entrants in more than 70 metalworking and fabricating establishments in the same area. The objective of this

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[1] Manpower Development and Training Act of 1962, as amended through October 24, 1968 (42 U.S.C. et seq.), Sec. 102 (3): "The Secretary of Labor shall . . . appraise the adequacy of the Nation's manpower development efforts to meet foreseeable manpower needs and recommend needed adjustments. . . ."

[2] *Formal Occupational Training of Aault Workers* (Washington: U.S. Department of Labor, Manpower Administration, December 1964), Manpower/Automation Research Monograph No. 2.

[3] *Career Thresholds: A Longitudinal Study of the Educational and Labor Market Experience of Male Youth*, Vol. I (Washington: U.S. Department of Labor, Manpower Administration, 1970), Manpower Research Monograph No. 16.

study was to determine the kinds of education, training, and experience that were most likely to produce highly qualified workers.

Focus was on an examination of various training patterns based upon the performance of the workers trained, the duration of the training, and the subsequent years of experience needed to become all-round toolmakers or diemakers or tool and die makers.

Two-thirds of the sample were employed in companies with 1,000 or more employees. Less than 15 percent were employed in companies with under 50 employees. Fifty-six percent, a majority of all those interviewed, were employed in tool and die units which were composed of 11 to 30 workers.

The average age was 44.6 years; three-fourths were over 35 and under 65. Forty-five percent began their training before 1940 and nearly 30 percent during the 1940's. Seventy-four percent had at least 12 years of school. The older member of the trade (in his fifties or sixties) generally had less education (a year or two of high school at most) and had studied fewer key subjects than had the younger man; his training generally was at work, either as an apprentice or on the job. The younger member was usually better educated and was more likely to have studied key subjects, but was less likely to have had systematic training outside vocational high school or trade school, although the largest proportion of men received their training in the firm.

The researchers found that there were no important differences in the competency of the tool and die makers produced by the various training paths. It was not so much the training but the aptitudes and interests of the person that seemed to account for competency. Particularly relevant to this finding was the additional one that students were given little or no occupational guidance when they had to make a choice on educational programs. The lack of guidance may also help explain why the men took so many years of work experience to become fully competent in the trade. Even though the men almost unanimously rated practical work experience as the most useful part of their training, more and better occupational guidance, based on comprehensive information about the labor market, is clearly needed. So is a close look at the process by which workers develop skills as they climb the occupational ladder. Given these measures, employers of skilled manual workers might be able to develop personnel and wage policies that would attract capable recruits who would otherwise choose white-collar professional jobs.

CLASSIFICATION, USE, AND POPULARITY OF TRAINING PATHS

This study identified six routes by which men become tool and die makers: on-the-job training, vocational high school, picking up the trade, apprenticeship, vocational high school plus on-the-job training, and vocational high school plus apprenticeship.[4]

Training Paths

The two most common paths were on-the-job training and vocational high school; more than 40 percent of the men interviewed had received at least some of their training at vocational high school. Below is a distribution by training paths of the workers interviewed:

Training Path	*Percent Distribution of Workers*
On-the-job training	22.5
Vocational high school	22.3
Picking up the trade	15.5
Apprenticeship	14.3
Vocational high school plus on-the-job training	11.3
Vocational high school plus apprenticeship	9.8
Miscellaneous[1]	4.3

[1]Seventeen workers acquired their training in such a wide variety of ways that they would not fit into any of the above categories.

The variety of paths, each with a substantial number of followers, is important to any consideration of manpower training policy, as is the informality in even the most formal methods. The authors defined apprenticeship as a training system that included a certain amount of classroom instruction; however, at least one-half or more of the apprenticeship graduates studied reported having received no related instruction. Further, on-the-job training and picking up the trade can consist of the same thing, merely viewed from different standpoints; at a minimum, the dividing line can be fuzzy.

Nevertheless, this trade is not acquired casually. Over 80 percent of the men had received some sort of formal training, either in school or at work.

Ports of Entry and Lines of Progression

The work histories of the sample members indicated that, after completing their education, workers became craftsmen by following one of three sequences. The first sequence produced all-round machinists who then became tool and die makers. The second sequence produced all-round machinists and tool and die makers

[4]On-the-job training was defined as involving specific instruction in the shop by company personnel, but with no scheduled content or predetermined length. Apprenticeship followed a predetermined schedule, had a fixed duration of at least 2 years, and included related classroom instruction. Picking up the trade involved watching other workers, imitating them, and asking other workers or the foreman for instruction or help. Picking up the trade usually required experimentation on the job at the risk of the worker, and represented gradual accumulation of skill by progressively moving to more complex work. In practice, however, all training paths incorporated large doses of picking up the trade, whether or not the path explicitly arranged for some kind of instruction by designated individuals. Because this classification system is unique (as are others), it is almost impossible to make direct or exact comparisons of statistics between this and other studies.

simultaneously. The last, the most common, converted men who already were all-round machinists into tool and die makers. The first two sequences were associated with either apprenticeship or on-the-job training; the third, with either on-the-job training or picking up the trade.

Training also occurred in two kinds of settings. The first was institutional; i.e., a company apprentices school or the shop of a high school or technical school. Here the trainee learned to operate equipment under designated instructors and was removed from the shop or production floor. The second was on the job, where the trainee helped other men with their work and, in the process, was taught or informally absorbed the skills of the trade. The trainee also could work as a machine tool operator and set-up man for a prescribed period in a production department as part of a formal training program. The man who already was a machinist normally was taught in the shop, working with or under journeymen tool and die makers. However, many boys just out of school and inexperienced men also learned in this fashion.

Men usually became all-round machinists first; they then became tool and die makers by working in a shop and either picking up the trade or by receiving informal on-the-job training. Learning simultaneously to be a machinist and a tool and die maker normally was confined to small job shops, where the trainee was taught to run machine tools by helping to prepare stock and later by machining components for jigs, fixtures, and dies. Large companies were more likely to train a man first to be an all-round machinist in an institutional setting, and to follow this with prearranged assignments to production departments as a machine tool operator and set-up man. He then could be assigned to a tool and die unit as part of his formal training program as a tool and die maker, or after he had become a journeyman machinist. In the latter case, he ordinarily picked up the trade; in the former, he was more likely to receive informal on-the-job training.

Men also became all-round machinists and later tool and die makers by being upgraded. They began as single machine tool operators and set-up men on simple production runs and gradually learned to operate and set up other machine tools until they eventually could handle most shop equipment and were in a position to learn tool and die work. If the men were then transferred to a tool and die department, they gradually learned the trade by machining components for journeymen tool and die makers or by helping one of them repair tools and dies.

Thus, many men did not become tool and die makers immediately after their formal preparation. In addition to their often being employed as machine tool operators or as machinists until the chance came for tool and die work, or being employed as machinists in tool rooms, assisting tool and die makers, there were frequently interruptions of other sorts. Men's progress was halted by inadequate opportunities, failure to perceive opportunities, misinformation, uncertainty about occupational interest, or poor health. (See appendix A.)

Trends in the Popularity of Paths

The popularity of paths has shifted over time as economic conditions have changed. (See table 1.)

For men who began their training before 1930, apprenticeship and vocational high school were important. During the depression of the 1930's, when jobs were scarce and experienced workers plentiful, training paths which required the trainee to be employed, such as apprenticeship, were little used. The lack of jobs and of training opportunities encouraged youth to stay in school as long as possible. The most frequently used training path at that time was vocational high school alone, followed by vocational high school combined with either apprenticeship or on-the-job training. Also, longer run forces, such as the rise in the age of compulsory school attendance and the expansion of public high schools during the 1920's, must have accelerated the shift to vocational high school during the 1930's and help to explain its earlier importance.

The demand for skilled workers rose sharply during World War II when urgent production needs called for rapid training. Many employers were satisfied with narrowly trained workers who might barely meet minimum standards of workmanship, so teams of specialists led by a few skilled craftsmen became prevalent. This practice lowered the ratio of tool and die makers to output and reduced the relative need for extensive training. Partially trained men were upgraded, and inexperienced men were put through intensive training programs. On-the-job training and picking up the trade became the two most prevalent methods; vocational high school alone or combined with either apprenticeship or on-the-job training withered.

In the postwar years, on-the-job training by itself and picking up the trade declined, but not to prewar levels, as apprenticeship and vocational high school promptly regained some of their popularity. The availability of veterans' training benefits seemed to be responsible for some of the revived interest in apprenticeship as a single path. A return to peacetime educational patterns may have accounted for the gain made by the vocational high

Table 1. Percent Distribution of Tool and Die Makers by Training Path and by First Year of Training

Training path	Before 1930	1930-39	1940-44	1945-54	1955-66
On-the-job training	14.8	11.6	36.6	27.3	26.3
Vocational high school	21.3	34.8	11.3	21.2	14.0
Picking up the trade	13.1	7.1	28.2	16.2	19.3
Apprenticeship	26.2	8.0	8.5	17.2	15.8
Vocational high school plus on-the-job training	8.2	17.0	8.5	11.1	7.0
Vocational high school plus apprenticeship	9.8	15.2	2.8	6.1	14.0
Miscellaneous	6.6	6.3	4.2	1.0	3.5
Total	100.0	100.0	100.0	100.0	100.0
Apprenticeship and combinations	36.0	23.2	11.3	23.3	29.8
Vocational high school and combinations	39.3	67.0	22.6	38.4	35.0
On-the-job training and combinations	23.0	28.6	45.1	38.4	33.3
All industry training	59.0	51.8	56.4	61.7	63.1

schools. Vocational high school combined with apprenticeship has had a sharp revival since 1955.

Nearly one-third of the entrants since 1955 served apprenticeship, either alone or combined with some other form of training. There is no indication yet that Federal manpower programs enacted after 1960 have affected the training of tool and die makers.[5] Moreover, there would have been too little time for men who began training after 1961 or 1962 to have become qualified craftsmen by 1966, when the study was conducted.

As the educational level of the average worker continues to rise, one can anticipate greater dependence upon formal education, at and beyond the high school level, as a means of occupational preparation for technicians and skilled workers, including tool and die makers. One also can anticipate that there will be relatively fewer men with only formal shop training, and possibly more men without such training at all. Shorter shop programs are also likely, as classroom instruction is substituted. Greater reliance on the classroom is especially likely if the trade becomes more complex and requires more theoretical understanding and mathematical knowledge.

[5] The 2-year limit on length of training would preclude full training for tool and die makers.

MEASURING TRAINING EFFECTIVENESS

Factors Measured

Probably the study's most provocative finding is that the training paths differed so little in their effectiveness. Indeed, Horowitz and Herrnstadt found that no single training path was significantly superior to the others.

The authors examined the effectiveness of each training path in terms of the performance ratings (based on accuracy, speed, and breadth of skill) given to the men by their supervisors; the length of time spent in training; the amount of time the tool and die makers estimated it took from the start of training after their formal schooling (including vocational as well as other secondary schooling) to become all-round competent craftsmen; and the time it took to be classified initially as toolmakers and diemakers. (See table 2.)

Because of the difficulty of obtaining cost data, they had to be excluded from this study. Since the results of various training paths are about the same, however, it becomes especially important to know whether there are

Table 2. Measures of Effectiveness of Training Paths

Training path	Performance rating (percent)		Average duration of training [years]	Median time[1] men estimated they needed to become all-round— [years]		Median time[1] men took before they were classified as— [years]	
	Above average	Below average		Toolmaker	Diemaker	Toolmaker	Diemaker
On-the-job training	42.7	14.6	2.9	9.0	11.0	8.0	9.0
Vocational high school	52.3	11.4	2.7	10.0	12.0	7.5	7.5
Picking up the trade	41.9	9.7	7.3	10.0	12.5	9.0	10.0
Apprenticeship	42.9	16.1	3.4	7.0	10.0	9.0	9.5
Vocational high school plus on-the-job training . . .	44.4	6.7	4.6	9.0	10.0	11.0	10.0
Vocational high school plus apprenticeship	56.4	2.6	5.5	6.5	8.0	8.0	7.0
Miscellaneous	35.2	5.9	6.4	7.0	10.0	13.0	16.0
All paths	46.0	10.9	4.2	9.0	11.0	9.0	9.0

[1] Excludes time spent in secondary school, vocational or otherwise, if part of compulsory schooling—unless the man had relevant training or work experience while still taking compulsory schooling. The time is measured as the number of whole years which elapsed between the first relevant training or work experience after the man entered the labor force full time and the year when he considered himself to be a competent craftsman or became classified as a toolmaker or diemaker. In determining the starting year, only jobs in the machining trades counted as relevant work experience. Thereafter, however, neither type of job nor labor force status (e.g., military service) affected the measure of time elapsed.

any significant differences in the costs of arriving at the same level of proficiency.

No path ranked first on all the measures of effectiveness. However, vocational high school combined with apprenticeship scored best on most counts. It had a high proportion of men with better than average performance ratings, required the least time to produce an all-round toolmaker and an all-round diemaker, and took the shortest time for a man to be classified as a diemaker. It also involved only moderately long training.

The effectiveness of the other paths was mixed. No path was consistently poor in all or most measures. Those men who had vocational high school only had high performance ratings, but not significantly higher than men from other paths, and took a short time to be classified but a long time to become competent. Two paths, on-the-job training by itself and apprenticeship by itself, were characterized by relatively short or moderate times, but performance ratings were not outstanding. The remaining path, vocational high school plus on-the-job training, produced neither exceptional ratings nor exceptional training times.

Performance Ratings

In rating accuracy, speed, and breadth of skill,[6] the foremen judged at least 40 percent of the workers from all training paths (except the small miscellaneous "group") to be above average or well above average. In the path that combined vocational high school with apprenticeship, and in vocational high school by itself, the proportions of men with better than average ratings were 56.4 percent and 52.3 percent, respectively. Few men in any path were rated below average. The spread was from 2.6 percent of men who had coupled vocational high school with apprenticeship to 16.1 percent of men who had had only apprenticeship. These two paths and vocational high school alone had the smallest contingents of men with just average ratings—about 40 percent in each case.

Age, education, years in the trade, years of job shop experience, duration of training, and training path, alone or combined, accounted for surprisingly little of the variation in the men's ratings as tool and die makers.[7] The only statistically significant factors were age, years in the trade, and years in a job shop. All these variables helped performance in a small way, but some worked against each other. Older, more experienced men tended to be more competent, despite less education, than younger men, but age began working against them by the mid-forties. The advantage of additional experience diminished or disappeared by the late forties; however, the effects of aging were extremely small.

That so little of the differences in ratings is explainable by the variables examined probably was due partly to problems of measurement. (See the discussion of this problem in appendix B.) Despite careful classification, the paths may not be completely mutually exclusive. For example, the authors defined apprenticeship as a training system that included a certain amount of classroom instruction; yet, as mentioned earlier, one-half or more of the apprenticeship graduates reported having received no related instruction. Under such circumstances, apprenticeship looks more like on-the-job training.

The weakness of the explanatory variables can also be attributed partly to the fact that age and experience helped to compensate for the older men's lower education.

But there may be a number of other reasons for the seeming irrelevance to performance of the kind of training, and the failure of any path to stand out markedly.

First, factors other than training might be crucial determinants of performance. Two frequently mentioned by foremen and the men themselves were innate talent[8] and the amount and variety of work experience. In

[6] Speed was rated on a 5-point scale from very slow to very fast. Accuracy ratings were based on the ability to build a tool or die correctly and to work to close tolerances, using a 6-point scale from poor to excellent. Breadth of skill ratings measured the complexity of the work (i.e., the shape and number of components, the number of moving parts, and the tolerances required) to which a man had been assigned or was judged capable of handling. This determination was made by having the foremen select, from arrays of 29 tools and 35 dies, the most difficult task which each man could perform.

[7] The coefficient of multiple determination for the six variables ($R^2 = .07$) can be interpreted to mean that they accounted for only 7 percent of the variation in performance ratings.

[8] The author's interpretation of "innate talent" is that it encompassed such attributes as mechanical insight and cleverness, a retentive memory (at least for things mechanical), and a strong desire to learn and to keep on learning. An "above average" tool and die maker, it seemed, was a "natural." He almost instinctively understood mechanical principles and liked working with his hands. He could store in his head "tricks of the trade" and readily recall them, even years later, as needed. He also was inquisitive about work being done around him, constantly observing what other craftsmen were doing. He was willing to ask questions. As a result, he was continually learning, accumulating better ways of doing old jobs, and keeping up with new techniques and materials. An average man had similar characteristics, but moderated.

The 1965 *Dictionary of Occupational Titles* (Vol. II, p. 430) lists among worker requirements for machine operating occupations the following: visual acuity, eye-hand coordination, ability to adapt to fluctuating situations, and ability to comprehend and apply mechanical principles. *The Dictionary of*

other words, performance was the result of a man's potential and some period of seasoning. Three-fourths of the men went into the trade because they had "natural ability"; and seven-eighths of them had a "liking for the work." There is no evidence that these men were not randomly distributed among the different paths. Men who discovered belatedly that they were not interested in or suited for the work may have left the trade voluntarily or may have been weeded out by the employer. Although careful screening procedures are likely to be used in formal programs such as apprenticeship, their use is not standard nor are their results completely accurate even if innate ability could be measured precisely and were the only factor considered in screening. Moreover, continuing tight labor markets since the early 1940's, and the longrun growth in educational opportunities and job alternatives available to young people might have circumscribed the choices even for established programs in prestigious companies.

In addition, all training, irrespective of name, shares common elements, which can be executed well or poorly. Training ultimately consists of an experienced person explaining to, or showing, a less experienced person what to do, or giving him help and advice. If the essence of training is this elemental relationship, effective training can occur under many guises and cannot be defined completely by such formal attributes as scheduled assignments or related instruction. Many strategic elements cannot be specified or controlled by formal standards; training can be erratic and disorganized because of interruptions caused by layoff, transfer, military service, illness, or personal indecision. There are large differences in the quality of training bearing the same name and, according to the study, there are as many differences within training paths as among them.

The differences among men with above-average, or well-above-average ratings were largely in accuracy and speed, rather than the breadth of their skill. Virtually all of the men in both groups could build the entire range of tools or dies, but a man did not receive a well-above-average rating unless he was also outstanding in either speed or accuracy and above average in the other.

Variations in breadth of skill did differentiate between men with better than average ratings and men with just average ratings and between men in the latter group and those with below average ratings. Only three-fifths of the average toolmakers could make the full range of tools and only two-fifths of the diemakers with average ratings could make all the dies. A majority of these men had above average accuracy, but their speed was just average. Nearly all of the men with below average ratings could do only simple tool and die work, or they were unusually slow with unpredictable accuracy. They often were assigned the making of parts under the supervision of more expert men.

The ratings of men who had served apprenticeships were similar to those of the other men, although those who had been apprenticed were older and had less education.

Neither the failure to finish training nor enrollment in part-time courses affected men's ratings. Inability to control such factors as course quality, subject variety, and years of study may have been responsible for the finding about part-time courses. Although men who had applicable training in the Armed Forces were rated somewhat better than were other men, the evidence suggested that this training was not responsible. It usually was not the way they had learned the trade.

How Long Does It Take?

There were three categories of paths with respect to duration of training: (1) a short one, averaging 2.9 years, composed of vocational high school only (2.7 years), on-the-job training only (2.9 years) and apprenticeship only (3.4 years); (2) an intermediate one, averaging 5.0 years, composed of vocational high school combined either with on-the-job training (4.6 years) or apprenticeship (5.5 years); and (3) a long one, consisting of picking up the trade, that averaged 7.3 years. The addition of vocational high school to a path lengthened it. But assuming that a certain number of years of secondary school are mandatory, vocational high school shortened training time. Men without vocational schooling spent more time in apprenticeship or in on-the-job training than men with it.

Regardless of the path, a certain minimum number of years of work experience appeared to be necessary before a man felt he was a competent craftsman. Men rarely considered themselves all-round craftsmen immediately after they had finished a formal program. The shortest path was vocational high school combined with apprenticehip. Toolmakers and diemakers trained this

Occupational Titles notes that success and interest in mathematics and technical subjects and leisure time work with machines are helpful clues relating applicants and requirements.

How essential to individuals with these characteristics are the number of years of formal education, the particular kind of training program, or experience in the trade? Can education, training, and experience compensate for an aptitude that is lacking initially? Since such variables explained so small a part of the differences in worker competency, it is unlikely that minor changes in any of them would have a marked effect on performance.

way estimated that they needed 6.5 years (median) of training and work experience after compulsory schooling to become competent all-round toolmakers and 8.0 years to become competent all-round diemakers. Time estimated by those whose path was apprenticeship alone was nearly as short for toolmakers (7.0 years), but not for diemakers (10.0 years). Vocational high school by itself and picking up the trade were the longest paths for both toolmaking and diemaking. Both took from 10.0 to 12.5 years to produce a proficient toolmaker or diemaker.

Generally, men got jobs that were classed as tool making jobs when they felt fully competent (the median time was 9.0 years), although this was not true of some paths. In contrast, men in all but one path were classified as diemakers before they felt qualified. Men were classified as toolmakers after they felt competent if they followed paths with formal, organized training, and before they felt competent if they had informal training or no systematic training after compulsory schooling.

Men with machinist apprenticeships became all-round toolmakers as fast as did men with tool and die apprenticeships, except when the latter had not attended vocational high school and had learned to operate machine tools before becoming apprentices. The apparent savings in time were substantial for men becoming toolmakers, but not for men who become diemakers.

Men under 35 seemed to achieve all-round competency and to be classified as toolmakers or diemakers in the shortest time—men 45 to 54 in the longest time. Economic conditions at the time of labor force entry probably were responsible. The older men began to work during the depressed 1930's, the younger men during the prosperous 1940's and the 1950's.

Men's Evaluation of Their Training

The study did not go into the specifics of what each man learned in the various training routes, but it did examine the men's evaluation of their own training.

There was nearly unanimous agreement among workers that practical working experience was the most useful part of their training, but that they could benefit from more formal education, more technical education, and most specifically, more mathematics. The two most often recommended types of training were vocational high school and apprenticeship.

Table 3. Distribution of Workers by Their Judgment of Value of Specified Subjects[1] in Tool and Die Work

Subject	Number				Percent distribution[2]		
	Little or no value	Average value	Great value	Total	Little or no value	Average value	Great value
Algebra	112	85	154	351	31.9	24.2	43.9
Binary number theory	5	2	1	8	62.5	25.0	12.5
Blueprint reading	4	13	376	393	1.0	3.3	[3]95.7
Calculus	32	6	17	55	58.2	10.9	30.9
Chemistry	131	16	4	151	86.8	10.6	2.6
Economics	54	13	5	72	75.0	18.1	6.9
Electricity	132	22	20	174	75.9	12.6	11.5
Electronics	35	11	12	58	69.3	19.0	20.7
Engineering mechanics	21	16	39	76	27.6	21.1	51.3
Heat treating	43	55	247	345	12.5	15.9	[3]71.6
Hydraulics	64	20	27	111	57.6	18.0	24.3
Machine theory	9	29	306	344	2.6	8.4	[3]89.0
Measuring instruments	2	14	376	392	0.5	3.6	[3]95.9
Mechanical drawing	21	50	278	349	6.0	14.3	[3]79.6
Metallurgy	23	49	140	212	10.8	23.1	66.0
Physics	113	64	33	210	53.0	30.5	15.7
Plane geometry	65	69	179	313	20.8	22.0	57.2
Solid geometry	36	40	85	161	22.4	24.8	52.8
Technical writing	14	10	14	38	35.8	25.3	36.8
Tool design	14	33	241	288	4.9	11.4	[3]83.7
Trigonometry	20	45	263	328	6.1	13.7	80.2

[1] Includes those studied in courses and those learned informally.
[2] Distribution may not total 100.0 percent because of rounding.
[3] Differences were significant statistically at the 0.1 level using the chi square test.

Table 4. Distribution of Workers by Equipment on Which They Had Received Training, Whether They Use It on Current Jobs, and Judgment Value of This Training for Current Skill

Equipment	Workers had received training		Workers use on current job		Workers' judgment of value of training for current skill (percent[2] distribution[3])		
	Number	Percent[1]	Number	Percent[1]	None or little	Average	Great
Boring mill	269	67.3	104	25.0	37.9	14.1	48.0
Chemical machining equipment	12	3.0	3	0.7	50.0	–	50.0
Cylindrical grinder	326	81.5	204	49.0	15.6	17.8	66.6
Do-all hand saw	395	98.8	370	88.8	6.6	18.2	75.2
Drill press	400	100.0	388	93.1	4.0	10.2	85.8
Electrical discharge machining equipment	113	28.3	66	15.8	25.7	18.6	55.8
Harding chucker	199	49.8	111	26.6	30.6	21.6	47.7
Honing equipment	320	80.0	242	58.1	14.1	22.5	63.4
Horizontal mill	353	88.3	266	63.8	15.6	14.2	70.2
Horizontal shaper	345	86.3	231	55.4	19.7	24.0	56.2
Jig borer	306	76.5	219	52.6	9.8	8.8	91.4
Jig grinder	154	38.5	92	22.1	12.3	11.7	76.0
Lathe	400	100.0	384	92.2	1.8	6.2	92.0
Numerically controlled equipment	38	9.5	16	3.8	34.2	18.4	47.4
Pantograph	130	32.5	55	13.2	38.5	20.0	41.5
Planer	263	65.8	69	16.6	51.7	14.4	33.8
Rotary grinder	267	66.8	156	37.4	21.3	22.8	55.8
Surface grinder	396	99.0	367	88.1	3.3	4.0	92.7
Universal mill	335	83.8	256	61.4	13.4	11.9	74.6
Vertical mill	378	94.5	326	78.2	7.7	8.5	83.9
Vertical shaper	278	69.5	146	35.0	33.8	17.6	48.6

[1] Percent of total sample.
[2] Percent of those who had received training on equipment specified.
[3] Distribution may not total 100.0 percent because of rounding.

Many workers either studied or acquired knowledge on the job of various subjects of direct use in their work. The most important of these were use of measuring instruments, blueprint reading, machine theory, tool design, trigonometry, mechanical drawing, and heat treating. (See table 3.) A clue to the importance of mathematics–it was felt least needed by men with above average performance ratings and most needed by those with lowest ratings.

Most key subjects required either up to 2 or up to 3 years to master. The usefulness of a subject did not depend on how or from whom it had been learned. However, some men apparently mastered material more quickly in the classroom and others outside it.

There were only a few basic machines which most men, irrespective of path or age, both used currently and considered highly valuable for skill in tool and die making. These machines included the lathe, surface grinder, drill press, and vertical miller. (See table 4.) Most men had become proficient on all machines except the lathe within 1 year; the lathe took up to 2 years. The hours recommended for particular machines in the national tool and die apprenticeship standards thus do not seem high; if anything, the researchers believe that they are too low.

Many men had been trained to operate more machines than they used in their work or felt to be particularly valuable. Many of these tools were obsolete; others had specialized functions. One was used to meet close tolerances increasingly needed today. There also were modern tools embodying new processes (e.g., electrical discharge machining) or capable of achieving extreme accuracy (e.g., the jig grinder) which relatively few men had been trained to use, but which many thought were essential. The national tool and die apprenticeship standards, dating back to 1956, do not reflect such developments, nor the displacements of old equipment and techniques by newer ones.

Foremen and fellow workers were the chief sources of on-the-job instruction and help. The former were more important than the latter in solving work problems. Few men had had to learn to operate new or changed equipment, and those that did often taught themselves on the job, sometimes with the help of foremen, fellow workers, and representatives of

equipment manufacturers. In other cases, workers were instructed in the use of machines by one of these individuals.

The Schools' Task

One small segment of vocational education—machine shop programs in secondary schools in the Boston area—was studied. These programs were selected because of their importance to tool and die making and because of the finding that tool and die makers with a vocational education background seem to do slightly better than those without it. The study was concerned with the ability of the machine shop program to help youngsters make the transition from school to full-time employment.

The concept of transition can be translated into a number of school functions: (1) counseling students about an occupational choice compatible with their interests and aptitudes, and with longrun market needs; (2) teaching students skills that assure employability on graduation; and (3) helping place students in suitable jobs—which may include necessary job development. The study examined the counseling given students in selecting a career, student attitudes toward work and toward the machine shop trades, and their acceptance by employers.

One-half of the high schools surveyed had no full-time counselor or had one who concentrated on college preparatory students.[9] Placements handled by special placement staff in some of the schools usually did not begin until the senior year; the two schools that had cooperative programs were exceptions; there, placement and supervision began during the last part of the sophomore year and included periodic evaluation.

Despite inadequate occupational counseling, youngsters in vocational high school programs received training and found related jobs while in school and afterwards. Most boys could find their own jobs and viewed the schools' placement activities as a last resort. The vocational schools were not alone in the inadequacies of their counseling; problems began at the critical junior high school level. The schools generally had a limited influence on the occupational decisions of machine shop majors. These students either had made up their minds before entering high school, or had accepted the program in which they were placed, expecting to find a job after graduation.[10]

The number of students in machine shop programs in vocational and technical high schools in Massachusetts was small and not growing as fast as secondary school enrollments. The programs in the vocational schools differed widely in content and in employers' evaluations of them. Schools that had selective admission policies; taught modern shop practices; and gave academic courses in algebra, trigonometry, geometry, and mechanics were rated best by employers. These schools could place their better students in jobs that offered the best opportunities to become all-round machinists or tool and die makers. The majority of vocational high schools, however, lacked community support, and many of their students did not obtain the better jobs that were available.

For routine machine shop work, employers preferred high school students with desirable attributes who had no vocational training over vocational students from programs and schools with poor reputations. In such cases, a youth's skill was considered less important than his attitudes, work habits, and his longrun potential. Nevertheless, students graduating from programs with poor reputations, as well as the less able students from programs with good reputations, were not left jobless. The draft and the tight job market for machine shop skills were important factors.

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[9] The Advisory Council on Vocational Education reported that only about 50 percent of American high schools provide any form of vocational guidance. The Council called for some form of vocational guidance during a large part of a person's educational career. *Vocational Education: The Bridge between Man and His Work*, General Report of the Advisory Council on Vocational Education (Washington: U.S. Department of Health, Education, and Welfare, Office of Education, 1968), p. 8.

[10] Nearly half the seniors really wanted to do something completely alien to metalworking. Only a third really wanted to be a machinist or a tool and die maker. One quarter wanted to work in a related field such as drafting, engineering, etc. However, about 70 percent of the seniors intended to take or had already taken a job in the trade or a closely allied occupation.

SOME OBSERVATIONS AND RECOMMENDATIONS

One finding confirmed by this tool and die study is the diversity of training and of ports of entry, even in this highly skilled occupation. The importance of this is apparent, considering the cyclical and secular changes in our society and economy, and the necessity for individuals to adapt to these changes. Because of the various training paths, there is great flexibility in length and content of training.

This finding is reinforced by the researchers' conclusion that there is no one best way to train tool and die makers. Discussions with men in the tool and die trade often elicited the following kind of explanation: "If you don't have a natural talent for this work, the rest doesn't count." Traditional recruiting methods do not reach some youth with natural aptitude, and the use of arbitrary selection standards may bar some who are highly motivated to become tool and die makers. Better recruiting and screening should lead eventually to a high proportion of above-average tool and die makers who need less time to acquire the basics of the trade and, possibly, less time to become accomplished craftsmen. Researchers, students, workers in the trades, employers, and vocational advisory councils all agree that we fail to offer professional, expert guidance for the high school youth whose plans do not include college.

Schools and employers might develop cooperative arrangements to employ vocational high school students during summer vacation or part time, year round as helpers and trainees, in order to acquaint them with the trade and arouse their interest in it. Employers could identify youth with a bent for metalworking, and youth could acquire firsthand information about the trade.

An important finding of the study is that the all-round tool and die maker, toolmaker, or diemaker is needed less frequently than the man whose training and skill is more limited. According to the study, only a minority of shops needed men who were all-round tool and die makers. Different organizations of work in different shops reveal that all work did not have to be done by journeymen. Some preliminary steps serve as natural training opportunities.

Yet most employers wanted toolmakers, diemakers, or tool and die makers who could build the entire range of tools, dies, or tools and dies. Employers were not seeking men capable of a limited range of tools or dies. But, neither were they all seeking tool and die makers. Some wanted toolmakers, others diemakers, and the rest, a minority, tool and die makers.

Only a minority of the men were tool and die makers; toolmakers outnumbered diemakers in the sample. There also were subsidiary specialists, such as men who combined experimental machining and toolmaking, diemakers who also were moldmakers, and toolmakers or diemakers who spent most of their time as job grinders and jig bore operators. The organization of work in shops helped to account for some of this specialization. Some shops, especially in large companies, had separate tool departments and die departments. Contract shops, on the other hand, were likely to have men who handled both tool and die work; they used all-round machinists for some of the work. In some shops, less skilled men were used to machine parts and to build simple tools or dies.

Are there then several kinds of tool and die makers for whom different kinds of training are needed? The authors suggest a variety of programs. One program might develop broad-gaged men able to handle many techniques and assignments, including ones in related fields; another could prepare "experts" on a narrower range of work who are capable of handling its most difficult parts and keeping up with changing requirements. A third program might train men for less demanding phases of toolmaking or diemaking, to work under close control or supervision. For example, the first program might train only toolmakers who could make models and prototypes, and do experimental work, or only diemakers who could make molds. The second

might prepare toolmakers, diemakers, or tool and die makers who could lead group projects and who could build the most complex tools or dies independently, perhaps from sketches or verbal instructions. The third might train men who could make tools or dies of average difficulty, from detailed prints, and who could help highly trained leadmen with difficult assignments. Men admitted to the first two programs would have to be selected carefully for temperament, motivation, and talent; they should be well versed in designing, engineering mechanics, the machining properties of different materials, algebra, trigonometry, and possibly the programing of numerically controlled equipment.[11] The initial year of training might serve as a screening period for identification of men suitable for these distinct roles. If there are a variety of training options in a community (e.g., evening programs in trade schools), an employer's choice need not be the final word. A man can voluntarily take part-time courses that would equip him for a broader role.

A further question is: How much specific training is possible in advance? A program directed toward developing men able to do "everything" is designed to build a reservoir of skills, all of which will not be used immediately and perhaps may deteriorate or become obsolescent. The breadth and variety of the trade, as well as its changing technology, suggest that a training program ought not try to impart all aspects of the trade but primarily the capacity and desire to handle increasingly difficult assignments.

Training programs might mesh with the adoption of progression ladders that start with machine tool operation and gradually introduce tool and die work; these ladders would begin, where possible, with tool and die repairing, as is now done informally in some places.

Another finding of this study is that it generally takes less time to produce an all-round tool and die maker by systematic training than by picking up the trade or informal on-the-job learning. The need now is for a satisfactory way of measuring training costs to evaluate more effectively the various training routes.

A number of findings relate to course requirements. A majority of the men learned a number of key subjects (e.g., blueprint reading, use of measuring instruments, machine theory, and tool design) only after their regular schooling was behind them; this was probably because of late occupational choice and lack of guidance while in school. These subjects usually were learned in part-time courses or informally at work.

Some related classroom instruction seemed to duplicate material studied in high school. More than one man explained that he quit his related instruction as an apprentice (and thus never "graduated") because he was being "taught" what he had learned in trade school or had picked up as a machine tool operator.

Seniority and work assignment provisions in some union contracts seem to make it difficult to retain apprentices or to vary their work assignments when production needs fluctuate.

There has been a tendency in administering formal wage structures to "freeze in" less able men who were brought in initially as toolroom machinists or "class C" toolmakers and then automatically upgraded or advanced in grade when the labor market tightened. The absence of a differential between them and competent craftsmen in the shop often hurts morale.

One way of avoiding or minimizing such seniority and wage-structure problems has been to stabilize tool and die employment and to meet fluctuations in demand by subcontracting work to job shops. The job shops have met the overload by scheduling overtime, as well as by delaying deliveries to prime contractors. In some cases, contract shops have operated extra shifts staffed by "moonlighters" from large prime contractors who curtailed their own overtime. In other cases, employees of large contractors have subcontracted jobs on their own from the initial subcontractor. To be successful over the long run, greater use of subcontractors assumes that the latter will undertake training.

Finally, while recognizing the limitations implicit in making generalizations from a study of a single occupation in a limited geographic area, certain of the study's findings appear to be worth examining for their implications for future manpower policy and vocational education policy. These include the findings that it is the individual himself and the opportunities available rather than the type of training that determines the degree of occupational skill, and that general economic conditions are important in determining the proportion of men who achieved their training through one method rather than another at various time periods.

[11] In the course of field work, the researchers came upon new products, equipment, processes, and materials that required highly skilled versatile men. They also encountered changes in the division of labor in shops that engendered specialization and a reduction of the functions handled by individual men. These changes suggested questions about the nature of tool and die work, and about the objectives of training programs.

APPENDIXES

A. Case Studies of Training Progression

The following case histories indicate the kinds of interruptions and delays that occurred in two training paths where such discontinuities were least expected; viz., vocational high school combined with apprenticeship and vocational high school combined with on-the-job training:

Case 1. He graduated from vocational high school in 1938 and went to work for a large machine tool manufacturer as a lathe operator in the tool room. Two years later, he left to become an apprentice machinist in a branch plant of a rubber tire manufacturer. By 1943, he was repairing dies and setting up presses at this plant, and was classified as a tool and die maker, probably because of labor market and wage control pressures. He entered the Army in 1944, was discharged in 1946, and spent the next 3 years learning watchmaking at a technical school full time. In 1950, he was hired by a large manufacturer of electrical equipment to make and repair molds. He worked in several companies thereafter and by 1952 was making jigs and fixtures. He did not consider himself a competent all-round toolmaker until the early 1950's.

Case 2. After completing vocational high school in 1921, he served for 2 years as a machinist apprentice, but he did not finish. He then switched to "outside" work for health reasons. He worked at a variety of jobs unrelated to the machine shop or the tool and die trade until the late 1930's, when he was hired as a machine tool operator and set-up man at a Federal arsenal. He spent the next 5 years there, most of them as a machinist. From 1946 to 1950, he did some limited tool work which he picked up, for a machinery maker; from 1950 to 1952 he did die work, which he also picked up on the job. Afterward, he did tool and die work in various shops, picking up more of the trade in each from foremen and fellow workers. He was first classified as a diemaker in 1950 and as a toolmaker 2 years later, but he did not consider himself an all-round craftsmen until 1961.

Case 3. He went directly into a machinist apprenticeship after finishing vocational high school in 1918. He completed his apprenticeship in 1923 and continued until 1940 with the same firm, a manufacturer of musical instruments, where he was successively an instrument maker, a tool and die maker, and a machine shop foreman. He was formally classified as a toolmaker in 1930. He left the firm in 1940 and spent the next 15 months in a navy yard, first as a machinist and then as an instrument maker. In 1955, he was hired by his current employer as a machinist, and progressed to become an instrument maker and then a toolmaker. He felt he was a competent tool and die maker in 1927; this was 3 years before he was formally classified as one.

Case 4. He graduated from vocational high school in 1933 and spent the next 7 years as a machine tool operator and set-up man in the toolroom of a large electrical equipment manufacturer, where he made parts for tool and die makers. In 1940, he went to work for a navy yard, where he was classified as a machinist after finishing an accelerated 18-month on-the-job training program. With demobilization, he was laid off and spent the next 3 years as a machine tool operator and set-up man in the tool room of a machinery manufacturer. He was hired in 1949 as a machinist by the firm in which he was currently employed, a small shop without formal classifications, but he has made jigs and fixtures most of the time there. He considered himself an all-round toolmaker in 1955.

B. Limitations of the Data

The classification scheme used in this study has a few unavoidable disadvantages. First, it relies on men's memories and their awareness of what happened. Second, there is no way of knowing what proportion of men's training time involved learning and what proportion repetition of what they already knew. Only a longitudinal study could cope definitively with these problems. Such a study would have to examine the training men received and then follow their careers afterward. A cross-sectional study such as this cannot duplicate this. Finally, the classifications should not be interpreted to imply that training programs with the same overt characteristics were identical. There undoubtedly was variation in the content and quality of programs with the same generic title.

Even the apprenticeship standards for tool and die makers registered in the U.S. Bureau of Apprenticeship and Training leave room for differences in content, duration, and instructional methods. These standards are silent about instructors' qualifications and the adequacy of equipment, and they say little about how and where training is to be conducted. For instance, is it to be in the shop or in an apprentice school? Moreover, shops differ with respect to the ability and personality of the journeymen and supervisors who serve as instructors, and with respect to the equipment and variety of assignments on which the trainee works.

Possible sources of variation in training are differences in the equipment in the employer's shop, the products made, the method of instruction, the stage at which tool and die work is introduced, and the personalities of the instructors and other mentors. Smaller shops, for example, may still use shapers instead of millers; or a shop may concentrate on draw dies rather than complex progressive dies. Some programs concentrate initially on the operation of machine tools; the apprentice, for example, makes a variety of machined parts, but does not necessarily help make jigs, fixtures, or dies. In other programs the apprentice helps make tools and dies almost immediately, at the same time that he is acquiring proficiency on machine tools.

The method of instruction can also differ. In larger companies, the apprentice may spend his first 2 or 3 years in training under an instructor, and then be transferred to a production department where he completes his training as a machinist by operating and setting up various machine tools under actual production conditions. In small companies, the apprentice, particularly if he has some machine shop experience, may be placed under an experienced tool and die maker. In effect, the apprentice is a helper who learns to a large degree by questioning, observing, and experimenting. Obviously, the personality and attitudes of the mentor, and the amount of supervision and help he provides, can be crucial variables here. In such situations, the time spent on various machines and in making different tools and dies can vary considerably. Finally, not all programs require related training; where they do, not all enforce attendance rigorously.

Each of the three measures of training time had drawbacks. Common to all the measures was the reliance upon individuals' memories and interpretations of experience for the basic data. The measure of the time needed to attain craftsman's status depended heavily upon the judgment and self-evaluation of individuals and their willingness to be candid. It also depended upon individual interpretations of what constituted a tool and die maker, despite criteria offered by the researchers. There is no practical way of solving this problem in a cross-sectional study that seeks information about the past. Corroborating the results with earnings data, even if they were available and accurate, could provide an answer if a man's relative wage at a given moment were a reliable gage of his relative performance and if it were not much influenced by such factors as length of service, the products made in a shop, its size, and its profitability.

A problem peculiar to the measure of the duration of training was the implication that the intensity and the amount of training in a given time interval were the same regardless of the kind of training. In theory, training time might be defined as time a trainee spends receiving instruction and time he spends practicing what has been taught, but which he still cannot do competently; e.g., with acceptable speed and quality. Realistically, little training is "pure" in the sense that all or most of the time is devoted to "learning"; for example, a man's productivity rises as his training advances, so that less and less of his working time is absorbed by instruction or practice. In this study, training time was not defined in the pristine sense suggested earlier. Instead, it covered the period during which a man was in a recognizable training program or felt he was still "in training," even though he produced useful products. Use of the term "training" thus approximated its everyday usage.

Moreover, by not discounting for difference in intensity of training, the researchers properly retained factors that are responsible for variations in the length of training. If the interest is in delimiting the time spent in a "trainee" or "learner" status, prior to being accepted as "trained," the unadjusted concept is the correct one. On the other hand, if the interest is the cost of training, one might want to distinguish between the time spent learning and the time spent not learning but in presumably producing a marketable product or service.[1]

The more formal the training, presumably the larger the proportion of time devoted to "pure" training. Hence, in general, 1 year of apprenticeship is considered to be more intensive than 1 year of loose on-the-job training or picking up the trade. In the latter two kinds of training, relatively more time probably is spent performing tasks that do not involve learning. However, the difference between formal and informal programs can be exaggerated. The men in the sample indicated that formal programs were not necessarily well managed, and that as trainees they were assigned work they knew how to do well. Further, the practice of rotating men among production machining departments could be highly inefficient from the trainee's viewpoint, because a large part of his time was spent in repetitive work.

The measure of the time needed to be first classified as a toolmaker or diemaker assumed that a man's job title or wage rate is independent of conditions in the local labor market. Use of this measure also assumed that firms either had formal classifications or comparable informal designations for jobs of similar nature as toolmakers or diemakers for men who were still training or that men built tools or dies without being classified as toolmakers or diemakers.[2]

By omitting training acquired during compulsory school attendance from the lengths of time needed to attain craftsman's status and initially to be classified as a tool or die maker, the authors of the study in effect assumed that school made no contribution to training. No satisfactory way could be found of estimating how much training, as the term was defined in this study, was represented by partyear attendance at a vocational high school or in the study of vocationally relevant subjects such as algebra in other high schools.

Finally, both of these measures cover the time which had elapsed from the start of the first relevant training or work after the men entered the labor force full time. Changes in economic conditions, international crises, and personal decisions caused disruptions in all paths, and decades elapsed before some men felt competent. (See appendix A, Case 2, for example.) Furthermore, as pointed out earlier, a "true" measure of training time would eliminate irrelevant or duplicative experiences, but this could not be done in this study. Nevertheless, the two measures give a realistic picture of the time needed to achieve craftsman status or to be classified as a toolmaker or diemaker in labor markets in which occupational progression is neither steady nor automatic, and in which forces beyond the individual's control help determine success or failure.

[1] Disentangling time spent learning from time spent not learning in a training program would have to cope with the fact that both frequently occur together; that is, they are joint products. The more realistic approach would be to determine the amount of marketable product the trainee makes and to deduct it from training expenses.

[2] Men first classified as, or considered to be, tool and die makers were also sometimes assigned specialized machine work, commonly jig boring or jig grinding. These men, however, subsequently had worked as all-round toolmakers and diemakers.

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